SENSORS & CONTROLS

Project Fact Sheet

FIBER-OPTIC SENSOR FOR INDUSTRIAL PROCESS MEASUREMENT AND CONTROL

BENEFITS

- Application to relevant problems such as real-time active combustion control, trace species measurements, and leak detection
- In-situ operation (no sampling equipment)
- Use of small, low-cost, rugged diode lasers that can be rapidly tuned, providing fast sensor time response (kHz data rates)
- Emission of very narrow band radiation, permitting higher sensitivity and rejection of interferences than possible with systems based on broadband lamp sources
- Use of near-infrared devices operating at or near room temperature; easily stabilized
- Significantly improved process and energy efficiency
- Reduced emissions of unwanted pollutants and greenhouse gases

APPLICATIONS

Real-time measurements and control of gas temperature and species concentrations will improve manufacturing processes in the forest products, glass, aluminum, and chemical industries. Applications include:

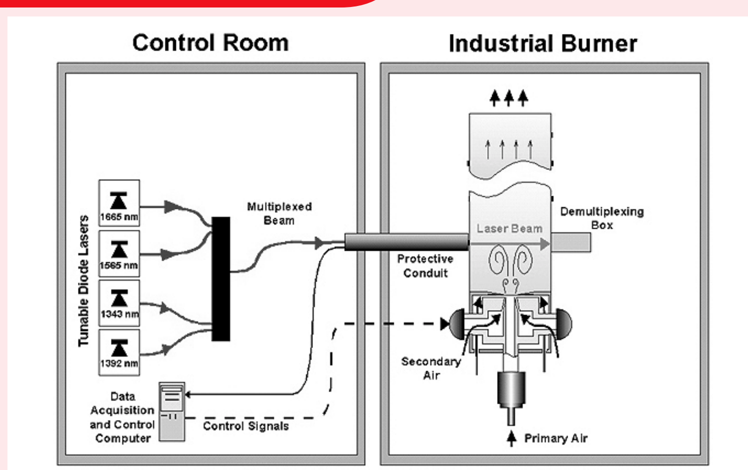
- Real-time measurements and control (including CO, CO_2, and hydrocarbon levels) in the combustion zone, above the glass melt in a glass plant, and in the exhaust
- Real-time monitoring and control of gas temperature and HF concentration above aluminum smelters
- Measurements of CO/CO_2 ratios and gas temperatures inside "pots," or electrolytic reduction cells in which alumina dissolved in molten cryolite is reduced to metallic aluminum
- Monitoring of CO, CO_2, and water vapor at various stages of the synthesis process for ammonia and urea production

ADVANCED DIODE LASER ABSORPTION SENSORS FOR CLOSED-LOOP PROCESS CONTROL OF INDUSTRIAL SYSTEMS

Many existing industrial process sensors have limited accuracy in applications involving highly corrosive gases at elevated temperature and/or pressure because they require extractive sampling systems that introduce variations in the temperature, pressure, and composition of the probed gases. Moreover, sampling systems introduce a lag resulting in >1-10 second response times, require frequent servicing, and may be subject to unexpected failures because of their complexity. Tunable diode laser absorption spectroscopy (TDLAS) affords a direct, quantitative measure of the species concentration in the probed region. In addition, by monitoring two or more transitions, the temperature along the optical path can also be determined. Near-infrared diode lasers are attractive light sources for sensing applications because they are rapidly tunable, small and lightweight, low-cost, efficient, and robust. They operate at near-ambient temperatures, and they produce narrow bandwidth radiation over a broad wavelength range.

This project will demonstrate the ability of diode laser-based fiber-optic sensors to reliably measure temperature and species concentrations (including CO, CO_2, and H_2O) simultaneously, in situ and in real time, thus providing opportunities for closed-loop control of a variety of industrial systems and yielding improvements in system efficiency. These on-line sensors can be combined with process optimization control strategies to enable significant improvements in plant throughput, increase product quality, and reduce energy consumption and waste.

TUNABLE DIODE LASER SENSING



This schematic illustrates use of laser-based fiber-optic sensors to reliably measure temperature and species concentrations simultaneously, in situ and in real time.

Project Description

Goal: Demonstrate the applicability of a TDLAS-based sensor for in-situ measurements of gas temperature and the concentrations of CO, CO_2, and H_2O under conditions relevant to the glass, aluminum, chemical, and forestry industries to enable real-time process control.

This project will use fiber optics to combine multiple laser beams at different wavelengths into a single probe beam. The resultant multiwavelength probe beam can be divided into several paths, allowing simultaneous measurements of temperature and species concentrations in multiple locations of an industrial facility. By combining fiber-optic and diode-laser technology with laser-absorption spectroscopy, a compact, rugged, and economical sensor system will be developed for species-specific measurements that are insensitive to interferences, particulates, and background emissions.

Detailed spectral modeling for the target species at high temperatures and pressures will be performed. Based on the information obtained, a breadboard TDLAS-based sensor for the measurements of H_2O, CO, and CO_2 concentrations and gas temperature will be assembled at the Stanford University High Temperature Gasdynamics Laboratory (HTGL). Initial H_2O, CO, and CO_2 concentration measurements will be conducted on a series of gas mixtures in a high-pressure, high-temperature sample cell. Gas temperature and H_2O concentration will be measured using fixed- and scanned-wavelength absorption techniques.

The diode-laser sensors will then be demonstrated for real-time measurements of temperature using water measurements in a laboratory combustion system at the HTGL, which simulates industrial conditions. A conceptual design of an in-situ sensor for harsh industrial environments was produced during Phase I. A TDLAS-based combustion control system is an eventual end product.

Progress and Milestones

This sensors and controls project was initiated through a FY 1999 Small Business Innovation Research (SBIR) Phase I solicitation, and it was selected to advance to Phase II in June 2000. All project tasks are scheduled for completion within 36 months. Key tasks that have been performed or are planned are:

- Conducted laboratory feasibility measurements to permit assessment of hardware specifications needed for the conceptual design of the prototype.
- Discovered a new, single-laser wavelength strategy for the measurement of water vapor.
- Developed and demonstrated a breadboard diode laser-based chemical sensor system in laboratory conditions replicating various industrial process environments.
- Identified Phase II demonstration test environment - 300 kW boiler simulator facility.
- Advance the breadboard system to a ruggedized prototype design for testing and commercialization.

Project Partners

MetroLaser, Inc. (Prime)
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High Temperature Gasdynamics Laboratory
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Air Quality Analytical
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